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ABSTRACT

Interpretation of experimental tasks is influenced by knowledge of the language used, by assessment of what the experimenter intends, and by how subjects themselves would normally represent the physical situation. Whether these processes in which children engage in cognitive studies differ from those employed by adults in similar tasks was investigated through a number of experiments which used different response criteria and different procedures. Focusing on proportional judgements of weight, area and volume the experiments demonstrated that when young children are given "sensible" tasks, they will perform better than expected. However, mature interpretation and performance by adults could not be taken for granted. In tasks derived from mathematics, science or logic, results suggested that cognitive processes might be increasingly hindered with age by interference from related but more familiar and more functional concepts, and from inappropriate experiential-rules from life. (Author)

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DEVELOPMENT OF THE CONCEPT OF PROPORTIONALITY FROM EARLY CHILDHOOD TO ADULTHOOD: THE IMPORTANCE OF CONTEXT[1]

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[1] A longer version of this paper, including fuller details of procedures and results, is available from the author.

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INTRODUCTION

Many studies on concept development tend to focus on changes in the accessibility and status of concepts (Flavell 1970). That is, they examine changes with age in, for example, the degree of articulation and availability for use in thinking. While they are interested also in consistency and accuracy of usage many have, however, made untested assumptions both about conceptual validity - how the concept agrees with that of the social community at large - and about adult performance in the same experimental tasks. (See, for example, an proportional concepts, Piaget and Inhelder 1956, Bryant 1974, Muller 1978, Bruner 1963, Nelson et al 1969, Siegler and Vago 1978.)

In examining continuity and discontinuity in cognitive development it is vitally important to compare the experimental context of contemporary psychological research with that of the social context of development. Often in both contexts concepts are relational rather than absolute since a concept does not always have the same set of criterial dimensions : the quality of an object is relative to its context and the objects with which it is compared. In addition, in everyday life relationships between different conceptual dimensions, experiential rules, also tend to be variable and imperfect. This is in sharp contrast to the contexts from which many cognitive tasks are derived. In domains such as mathematics, science and logic, relationships are usually true, specifiable and fixed. Furthermore, in these latter contexts, rules are also transformational: one needs to carry out certain operations in order to discover or to use the rule. Again this differs markedly from the extra-experimental context where rules are inclined to be static. One does not need to do anything; the relationship is present in the meaning of the term.

This paper therefore, in focusing on continuity and discontinuity in development of the specific concept of proportionality, investigates

three important and inter-related questions. Proportionality is an important concept for mathematical theory and, according to Inhelder and Piaget (1958) a reliable index of logical reasoning, of 'mature' cognitive development. However, to what extent is the concept valid psychologically? How sensible are proportional problems in human terms? Secondly, do the processes of interpretation in which children engage differ from those employed by adults in the same tasks? These are processes which involve objective physical variables, subject variables and also a variety of interpersonal factors which operate between experimenter and subject and task (Donaldson, 1976, 1978); knowledge of the precise language used, expectations, assessment by subjects of experimenter's intentions - what he does as well as what he says, and how the subject would represent the situation in the absence of an experimenter. Thirdly, is concept development due to overcoming failures in understanding or failures in reasoning?

The series of experiments utilizes different response criteria and different procedures, and a variety of tasks invite children and adults to compare different conceptual dimensions, perceptual and abstract, and to process relational and proportional information with the conceptual dimensions area, weight or volume. Taken together the results of these apparently disparate sets of experiments become much more interesting and valuable than when they are treated as dealing with separate perceptual, conceptual or linguistic developmental issues.

EXPERIMENT 1

The first experiment set out using a triadic elicitation technique to investigate the salience of different cues: size, shape and proportion when they are set in an appropriate functional context.

SUBJECTS

Two hundred and eighty children with equal numbers of males and females in 7 age groups from 5 to 11 years (mean ages: 5:10, 6:10, 7:10, 8:5, 9:5, 10:6, 11:5; range 5:4 to 11:11) and forty adults (half male and half female; undergraduate psychology students).

METHOD

Verbatim instructions: "We are going to look at some pictures ... pictures of plates with chocolate cake in them ... Now look at these 3 pictures. Can you tell me in what way two of them are alike, that is the same, but different from the third one?" The last instruction was repeated.

There were four alternative sets of cards. Each subject was given one set which included five different groups of three white cards (8 cm square) with drawings on them. The five groups were presented in the same order. Each group either held constant or varied within the three cards the features size (big or small), shape (circle or square) and proportion shaded (half, quarter or three-quarters). For example as in Figure 1 (Set A, group 4) subjects could respond "both big" or "squares", or "half" etc. In every group one possible construct was the fraction shaded.

Figure 1 here

RESULTS AND DISCUSSION

Table 1 shows the number of subjects who made explicit reference to the functional context. Only 38 percent overall decoded the stimuli in concrete terms with a marked decrease for both the youngest

Table 1 here

and oldest age groups.

Types of responses were categorized according to subjects' descriptions. There were 5 main types:

1. F : <u>fractional</u> (or proportional) eg. "These have ½"
2. Q : <u>quantitative</u> (or relative amounts) eg. "These have more", or "go whole way across".
3. I : <u>internal shape</u> (or shape of 'cake') eg. "These are rectangles", or "have straight sides".
4. S : <u>external shape</u> (or shape of 'plate') eg. "These are circles".
5. Z : size of figure (or 'plate') eg. "These are big".

For the group as a whole patterns of response preferences at all ages were similar (Kendall Co-efficient of Concordance $W=0.76$, $p<.01$). Even the youngest subjects could compare accurately shapes within shapes and were adept at using appropriate formal mathematical labels like rectangles, squares, triangles, as well as describing features with references to simpler dimensions, using again mathematical concepts such as "both got points and straight sides" or by recourse to concrete referents such as "like moon", or "both like a house with a door".

Chi-square analyses both within and between the five stimulus groups and the four alternative sets showed, among other things, that seven to eight years was a pivotal age from describing the shapes of 'internal' features to using mathematical terms such as proportions or precise fractions. Once 'set' (Group 1) to focus on internal features, to figure as opposed to ground, overall size seemed unimportant (Group 2), although shape of outline-figure remained a salient cue (Group 3). In Group 4, where all three physical cues were possible constructs, the 5 and 6 year olds decoded mainly in terms of shape. With increasing age the subject produced proportional descriptions and size was

virtually ignored, although two small stimuli plus one big one, As opposed to the converse, made size a more salient one. Also, in circles fractional areas are more complex spatially and mathematically than similar portions of squares and this complexity produced more summary ratio labelling by the young subjects for the circles. However, when the child identifies two similar geometric shapes he is discriminating and matching formal ratios even without the ability to articulate the relevant mathematical rule. The use of appropriate ratio terms was facilitated especially for the two youngest groups, if the subject could match two halves rather quarters or three-quarters. It is important to note that all the present representations used symmetrical partitioning through the mid-point with right angles. One must be careful therefore not to conclude unequivocally that the subjects who used ratio labels had made their judgements by computing ratios mathematically; they may have used more primitive types of perceptual analyses which merely on occasions corresponded with appropriate formal mathematical descriptions. Ongoing studies therefore will include 'more difficult' ratio representations.

EXPERIMENT 2

The second experiment also involves discriminations of size and area and is part of a larger study on judgements of size ratios which impinges upon the debate concerning absolute versus relative coding in children. As Reese (1968) points out this is an old dispute between S-R theorists and Gestalt theorists but more recently of course, it concerns the opposing views of Piaget (1969, Piaget and Inhelder 1941, 1956, Piaget, Inhelder & Szeminska 1960) and Bryant (1974) regarding the use of absolute and relative codes, external framework cues and deductive inferences.

SUBJECTS

Ninety six children, sixteen boys and sixteen girls in each of three age groups: 4 years (mean age 4:4; 3:7-4:11) 7 years (mean age 7:5; 6:10-7:11) and 10 years (mean age 10:5; 9:10-11:1) and thirty two adults (equal number male and female; psychology undergraduate students).

METHOD

The task was to match a given ratio with one of three choices. Each subject was required to make eight judgements and controls were used for variations in the absolute size of the standard, distance effects, and increasing versus decreasing size, position and orientation. The task involved four sizes of stimuli : brown wooden circles of diameters 9 ins. (approx. 23 cms), 6 ins. (15 cms), 4½ ins. (approx. 11½ cms) and 3 ins (7½ cms). Each had a white Maltese Cross pattern painted on of three different proportions. As shown in figure 2 within each quadrant the proportion of white to brown was three to one, two to one, or one to three. The standard stimulus was always either three to one or two to one. Subjects' attention was drawn to the "nice iced pattern" all the way round a "cake" and the children were told that a fairy was going to wave her magic wand to make the cake either bigger or smaller. (Reference to the fairy was omitted for the adults). They were then asked to identify "the right cake" from among three.

Figure 2 here

RESULTS AND DISCUSSION

There were three categories of response:

1. Absolute ratio or proportional choice (precise matching)
2. Relative choice (more white than brown)
3. Error (more brown than white)

Table 2 here

Table 2 shows the mean scores out of eight for each age group. It might be argued that at least in some of the judgements the difference between some of the areas was insufficiently large - a question of psychophysical j.n.ds.-but even if the young child has difficulty in quantifying these ratios in absolute terms he can make relative judgements: just over one quarter of his choices only are errors. Also noteworthy is the negligible change between 7 and 10 years in relative and proportional responses.

However, as in the last experiment, the subject here may also be responding not to ratio information but to some other perceptual feature of the configuration, although unlike some of Bryant's (1974) work no simple one-to-one matching was possible. The adult subjects were therefore asked at the end of the session to state the basis in which they had made their choices.

Table 3 here

As seen in table 3, proportional explanations featured little. While even the pre-school child can code relative values, perceptible relationships seem to be more easily discernible or put into words - than precise quantitative ratios even for intelligent sophisticated adults.

EXPERIMENT 3

The third experiment, a simple preference task, shifts to the weight dimension. The first of an ongoing series of experiments, it concerns relationships between size and weight and attempts to achieve an incidental behavioural response.

SUBJECTS

Fifty seven infant school children with equal numbers in three age groups with approximately half boys and half girls at each age level. (Mean ages : 5 :3, 6 :5 and 7 :4; range 4 :9 to 8 :7)

METHOD

The children were told that they were going to look at some pictures and they were then given the Peabody Picture Vocabulary Test as per manual instructions. (Dunn, 1964). At the end of the session, in a casual spontaneous tone as in natural conversation E said, pointing to three fairly large boxes placed in random order on the floor in the corner of the room behind the subject and all equally accessible, "Oh, I wonder what's in those boxes over there. Shall we have a look? You go and bring over the heaviest one ... the heaviest one ... Oh dear! It's stuck. Never mind, we'd better just put it back."

The three boxes were sturdy cardboard cubes covered in blue fablon, sealed with sellotape. Their external dimensions were 7 inches (approx. 18 cms), 10 inches (approx. 25 cms) and 13 inches (31½ cms). Weight and size were inversely related. The largest weighed 3 lbs 11 ozs. (1.7 kg), the middle size ½ lb (0.23 kg) lighter, and the smallest 1 lb (0.45 kg) lighter than the biggest.

RESULTS AND DISCUSSION

While there was a wide range of verbal ability generally the results fell in the average range.

Tables 4 and 5 here

Table 4 details the number of subjects who selected each of the 3 boxes, and the number of boxes lifted prior to subjects making final choice is given in table 5.

There is a clear bimodal distribution. Seventy percent selected the largest box and all did so without lifting any of the other two boxes beforehand. Five percent selected the middle sized box and 25% the smallest box and the correct choice. Of the fourteen children c rect 71% lifted all three boxes. Thus only 18% overall fulfilled the strictest criteria - correct choice as the outcome of the appropriate

behavioural strategy.

Analyses for age and IQ were not significant for these subjects (χ^2 = 0.653 (df=3), 4.7 (df=4) respectively). Of the twenty eight children with MA less than six years 12% made the correct decision and of the twenty nine with MA of at least six years 24% were correct. However, the difference in these proportions is also not significant (Z= 1.28, p= 0.10). Therefore the criteria was relaxed to focus on weight lifting strategy. This produced fourteen subjects who lifted at least one box additional to the final choice, irrespective of this choice. Chi square analyses were carried out for age (χ^2=0.654, df=3, n.s.), I.Q. (χ^2= 4.7, df = 4, n.s.) and M.A. (χ^2 = 6.344, df = 3, p = .05) with Yates correction for M.A. 6 years versus 6 years or more (χ^2= 3.14, df = 1, p = 0.05).

Thus while there was no developmental trend within the age range studied (4 yrs 9 mths to 8 yrs 7 mths) and IQ is compounded by age, a mental age of six years seems to be the pivotal point in this task.

These results are interesting. Firstly, the attempt to achieve a naturalistic response at the end of an assessment session failed at least in the conversational sense; virtually no child spoke at all. Perhaps they were still suspicious of the strange adult, perhaps wary of being 'nosey' regarding other people's property. Also importantly, it is likely that fear inhibited the necessary overt behavioural responses, including ascertaining whether lifting all the boxes was actually permitted. It is possible that for some of these children this task might be received as a guessing game.

On the other hand of course, the task is non-ecological and hence problematic, however presented. In everyday life, size and weight usually co-vary - especially for objects identical in every perceivable perceivable dimension apart from size. Therefore the majority did not only focus on the most salient cue, size, but they were also making a response which was appropriate in terms of the extra-experimental context. They had internalized the usual rule.

INTRODUCTION

The remaining experiments also focus on the interaction between psychological development and mathematics and involve a similar fascinating interplay of verbal, behavioural and perceptual factors which operate between experimenter and subject and task in problems which illustrate physical proportion in terms of relative fullness. "Is one container fuller than another?"

In the original research on this water-jar problem Bruner and Kenney (Bruner, 1964, 1973, Bruner et al 1966) set out to trace the growth of the terms "full" and "empty" to their more adult usage - development towards the ability to deal with "the proper notion of ratio". Recent research by McWhirter (1977, 1978, in press), however, has suggested that adult connotations of the lexical item "fuller" may not conform to the strict dennotative meaning of relative fullness.

Ability to handle such comparative judgements of fullness involves the processing of perceptual cues plus a computing of relationships within relationships plus an advanced and differentiated comprehension of "fuller": the child must acquire an articulated formal system of rules which permits not only application of the absolute sense of the concept (full/empty or full/not full) or the asymmetrical sense (not/having reached the specified or usual limit - eg., full/half moon; not yet/fully grown dog;) but one which must also permit use of a continuous dimension of degrees of partial fullness where the obtained proportion can be computed.

According to the logical, mathematical definition of relative fullness and that imposed by cognitive researchers, the task comprises a two stage problem which requires first, computation of one of several ratios for each individual container: a) the ratio between the volume of each container and the volume of substance contained; b) the ratio between the volumes of filled and unfilled space; c) the ratio between the height of each container

and the height of its substance. Secondly, the task demands a comparison between containers of the two ratios obtained, whichever strategy is adopted. To answer correctly the child must be able to handle metric proportions and compare two ratios. Focusing on the absolute dichotomous sense of fullness and on equal proportions, Bruner and Kenney (Bruner 1964, 1973, and more fully reported in Bruner et al 1966) have demonstrated that by eleven years children can handle the inherent ratio judgements involved in deciding if one container is fuller than another, and a replication study by Nelson et al (1969) revealed that thorough training involving feedback enabled seven year olds to perform at an even higher level on similar comparative judgement problems.

More recently Siegler and Vago (1978) in a series of six experiments, but using only one of the three proportionality rules above, concluded that the difficulty for pre-adolescent children lay in integrating the component procedures. However, McWhirter (1977,1978, in press) has demonstrated that even by adulthood the subject seems to find the critical semantic features problematic. In life, and also in much of the empirical research, "fuller" usually coincides with "more". Not only are there common conceptual components between proportional fullness and volume of contained substance but there also tends to be perceptual, physical and functional equivalence. The present experiments therefore focus on the exceptional case where the fuller container is smaller on all possible perceptual dimensions.

EXPERIMENT 4

SUBJECTS

One hundred and ninety two preschool and primary school children with equal numbers of boys and girls in 3 age groups: approximately 4 years, 7 years and 10 years. Means (and ranges): 4:4 (3:7 - 4:11), 7:5 (6:10 - 7:11), 10:5 (9:9 - 11:0).

METHOD

1. PRETEST

The children were told that they were going to play a game and then E said casually and spontaneously inviting a behavioural response apparently incidental to the main task. "Oh, before we start I need some pages. Would you please reach me the pages over there (E pointing to an appropriate place on a table or shelf conveniently behind S and further away from E) - the pages under the fuller glass - the glass that's the "fullest". (See Figure 3).

Figure 3 here

The two sets of pages under the two containers were of equal heights but of different sizes and colours. The positions of the glasses were alternated between subjects. The glasses contained common salt.

After thanking the subject and ostensibly making as though to use one of the pages given, the experimenter continued with the main task, a play situation.

2. TRAINING SESSION

Producing four soft toys of approximately equal heights (two teddy bears and two rabbits) E said "I have brought 4 friends along with me to play the game. They would like something to drink". E then placed 4 glass cylinders which had been concealed (in random position) on a line on the table as in figure 4.

Figure 4 here

The two narrow glasses contained orange liquid, and the two wide ones contained a red liquid. The two shorter glasses were three quarters full and the two taller were half filled.

Each subject made three judgements with feedback. Choice of toy and the preferred colours of drink were randomized. Subject had to place chosen glass on the table beside the appropriate toy or person

1. One toy wanted a particular colour and his glass nearly full.

2. A second toy wanted the other colour and his glass half full.

3. Subject was asked to chose one of the remaining two glasses for himself (one of each colour) - either the one which was "nearly full" or the one which was "half full". The experimenter took the remaining glass for herself.

3. POST-TEST

Experimenter said spontaneously "Oh, we've forgotten about these other two toys" but came to the rescue with two more glasses containing the same colour of liquid (orange or red) as per figure 5.

Figure 5 here

Of these the subject had to place beside the third toy "the fuller one, the fullest glass" and the last toy was given the last glass.

RESULTS AND DISCUSSION

Table 6 here

Table 6 gives the percentage of subjects correct for each of the 5 comparative judgements.

A number of aspects of this data are of interest. First, analysis of the distribution of correct response within the training session shows that developmental trends were as predicted. The two older age groups showed the expected learning effect from pair one to pair two but even with feedback on pair one ("nearly full") the youngest children found pair two more difficult, ("half full"). Further, there was no significant improvement on judgements of "half-full" between pairs two and three (McNemar, χ^2 1.0, 0.44. 0.17, with Yates correction N.S. for any age group). For those subjects who preferred their own glass "nearly full" only the seven

and ten year olds revealed a significant improvement in performance (McNemar, χ^2 = 0.08, N.S. for 4 year olds, χ^2 = 9.0, 8.0, p<.01 for seven and ten year olds.)

However, it is more noteworthy that there is no developmental trend in the pre-test results. All subjects appeared to have accepted the request as quite natural but only 20% chose the pages from under the glass which was smaller in every way but relatively fuller although for all three age levels, the increase in percentages between pre and post-tests is highly significant (McNemar test χ^2 = 12.6, 23.27, 18.00, (df = 1) respectively, p .001). What is also of interest in the present context is the discontinuity in age distribution: there is an increase between ages four and seven but a decrease between ages seven and ten. Although the oldest children can correctly choose the precise proportions which are made explicit, less than 60% are correct in their judgement of relative fullness. Why? It seems improbable that the older children still have a problem of integrating the component operations (Siegler and Vago, 1978) since over 70% of the younger group (six and seven year olds) are successful following the brief training session. Experiments 5, 6 and 7 therefore pursue this question with adults.

EXPERIMENT 5

This simple little experiment involved a single behavioural response elicited in the process of normal activities.

SUBJECTS

Ten first year undergraduate psychology students: five male and five female.

PROCEDURE

In the first psychological laboratory class of ten groups of students a variety of papers had to be distributed detailing the work which lay ahead and introducing the first session. Five piles of such papers of approximately equal height were placed side by side in a line on a table at the front of the class. Each was weighted down with suitable laboratory objects including the two glass cylinders which were used in the pre-test in experiment 4.(see figure 3,) each containing salt to the same proportions (half and three-quarters). The position of these glasses was systematically varied between sessions but they were always beside each other.

In the process of normal class activities the teacher casually asked one student at the front near the table to help with the distribution by first giving out those under the fuller glass. The instruction was repeated once.

RESULTS AND DISCUSSION

All students accepted the request without question and 100% chose the wrong glass. Why?. The following group experiment therefore, like the previous one and also the McWhirter 1977 study, attempted to highlight the relevant and critical ratio features.

EXPERIMENT 6

SUBJECTS

One hundred and thirty one first year Psychology students.

METHOD

18

Groups of students were given out a short typed story. They were asked to read the story carefully and then to answer

in writing two questions which followed the story with reference to a diagrammatic representation.

There were 4 conditions in order to take account of variations in normal etiquette (giving or keeping the fuller glass) and to present the problem first linguistically without misleading and dominating perceptual cues. The diagram (as per figure 3) was projected on to a screen with three-quarters of the smaller glass being shaded orange and half of the larger glass coloured brownish-black.

The story was as follows, with the alternative version in parenthesis:

> Two students, John and Peter, were clearing up their flat after a party. One asked the other if he would like a drink.
>
> "Yes", came the reply.
>
> "What would you like"?
>
> "Anything, it doesn't matter"
>
> So John went into the kitchen, eventually found 2 empty glasses and a little vodka, orange and coke. A minute later he shouted to Peter,
>
> "One glass is nearly full and the other is half full. Which one do you want?"
>
> "Give me the fuller one" (or "You take the fuller one") yawned Peter.
>
> "What did you say?"
>
> "Give me the one that's fuller than the other John",
>
> (or "You take the one that's fuller than the other John".) repeated Peter.
>
> So John gave Peter the fuller glass. (or John took the fuller glass).

1. What did Peter (or John) have to drink with his vodka?
2. Why? Orange or Coke? _____

RESULTS AND DISCUSSION

Table 7 here

Table 7 gives the distribution of correct choices irrespective of explanations. Overall only 58% (n=77) responded correctly, a result which might have been achieved by chance factors. Analyses for differences in the four conditions furthermore was not significant ($\chi^2 = 2.57$, (df=2), N.S.), although the trends in the results are interesting. One favours the person keeping the fuller glass, which is of course also smaller and with less in it, in other words being generous and giving someone else 'bigger' and 'more'. The other favours those who were shown the representation first. This is perhaps tentative support for McWhirter's (1977) previous finding that the water-jar problem requires a concrete perceptual referent in order to make it tractable. Is it too difficult - or 'meaningless' - in words alone?

Analysis of the verbal justification given by the students is relevant however, to the understanding of how they coded the different information. Only 21% (n=28) made the correct judgement substantiated by a ratio-type explanation (reference to any of the three possible rules given earlier).

These results, allied to the previous findings seem to suggest an inability to locate the problem as intended by the experimenter. The final experiment therefore concentrates on the semantic aspects. It draws attention to the apparent conflict in interpreting the term "fuller".

EXPERIMENT 7

SUBJECTS

Thirty two second and third year undergraduate students of psychology.

METHOD

Subjects were asked orally in small groups "What do we really mean, that is strictly speaking, if we say that one container is fuller than another?" The question was repeated once and subjects had to define the term in writing.

RESULTS AND DISCUSSION

Looking from the least to the most frequent type of response it was seen that:-

1. 12½% expressed difficulty over the partial, relative dimension of the term feeling that the word referred only to some absolute state.
2. 16% gave definitions both in terms of greater volume of substance and greater ratio, recognizing relationships and possible conflict between the two.
3. 22% offered definitions in terms of ratios or proportions.
4. 50% interpreted the word purely in terms of comparions, between containers, of volumes. In order words, even when the meaning of the relative term was introduced as problematic half of these intelligent, adult subjects understood it to refer to physical contents. As one said "It is a typically Irish way of simply saying that there is more substance in one container than another!"

It might be suggested that not only do the Irish say and do foolish things but cognitive developmentalists throughout the world at times set up absurd experimental tasks. A major difficulty with the above comparative judgements is that the concept of relative fullness itself does not have a functional basis. In life the subject does not possess the concept of proportional fullness. The emergent picture suggests that perhaps the greatest problem is that the concept is not valid psychologically, in human terms. The task subjects receive differs

markedly from that intended by the experimenter, even when the relevant ratio cues and the critical semantic features are highlighted.

CONCLUSION

The present results obtained for different physical dimensions, from a variety of procedures and according to different response criteria clearly illustrate that the same processes of understanding that children use in experimental situations may also be used by adult experimental subjects. There is continuity not discontinuity in application of the skills of interpretation; from early childhood to adulthood subjects tend to extrapolate from the context of life to the experimental situation.

However, there is also evidence that given a situation which makes sense to them in child-like terms they can play the "experimenter's game". The young child can change his representation; he can give relative and proportional descriptions and make ratio judgements under certain conditions. The precise nature of these conditions is vital, socially, perceptually, linguistically and physically: the use of appropriate ratio labels may not be the result of proportional reasoning. However, 'mature' understanding and reasoning by adults must not be taken for granted in cognitive developmental research. The contrast between problem solution and problem identification is vital (cf. Siegler 1976) and the latter may be increasingly hindered with age by inappropriate rules, by interference from related ideas within the same conceptual domain, from concepts which are both more familiar and have a more functional or pragmatic core.

Researchers must confirm empirically the validity and precise developmental goal of concepts, particularly 'fuzzy' concepts. Perhaps then they will be better informed about the nature of interpretation and reasoning in cognitive studies and of continuity and discontinuity in behavioural development.

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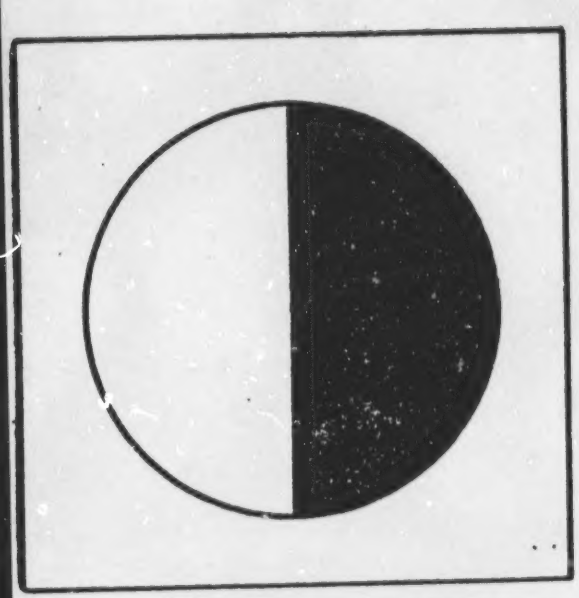
Figure 1

Experiment 1, Set A, group 4. The three stimulus cards.

Figure 1



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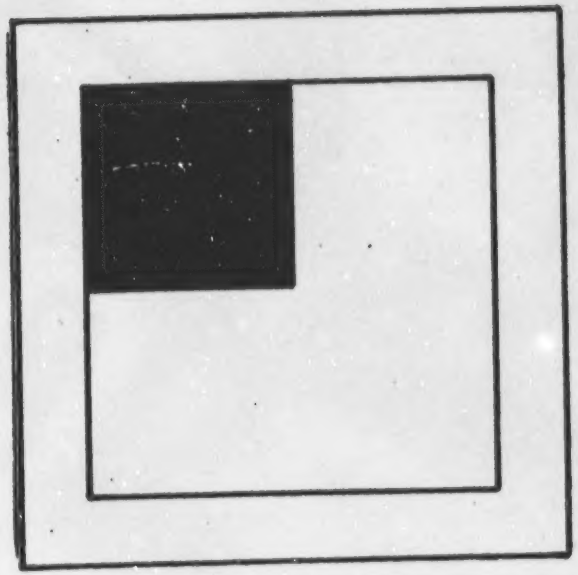

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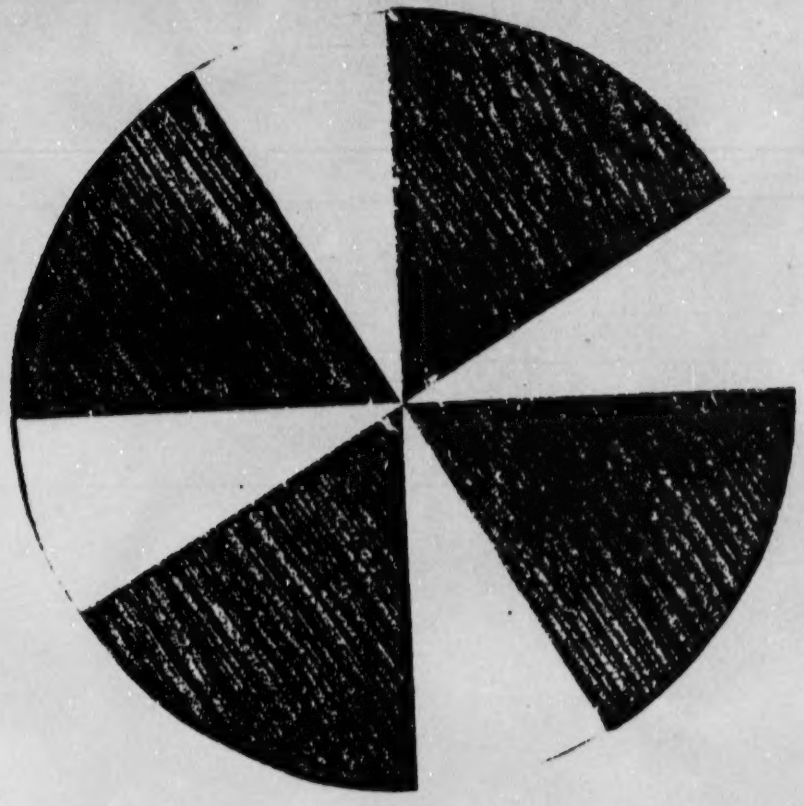
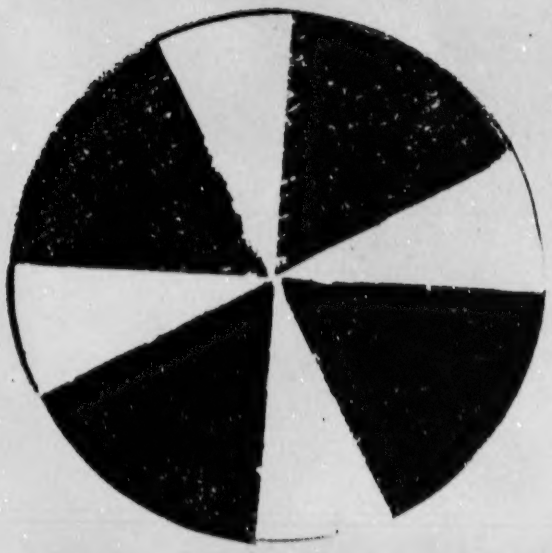
Figure 2

Experiment 2. The type of stimuli used in the matching task.

Figure 2



30



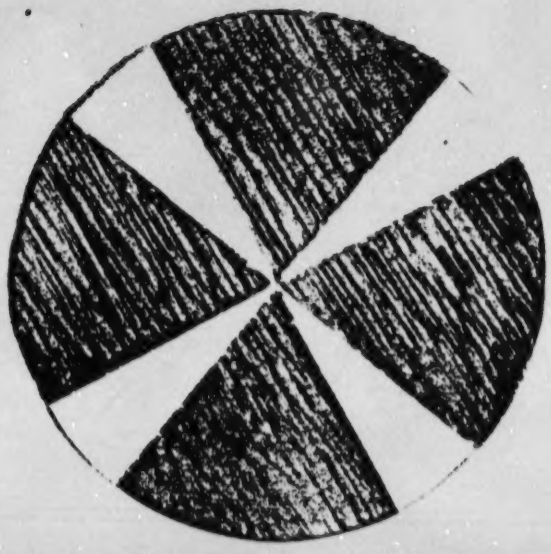


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Figure 3

Experiment 4. The glasses used in the pretest.

Figure 3

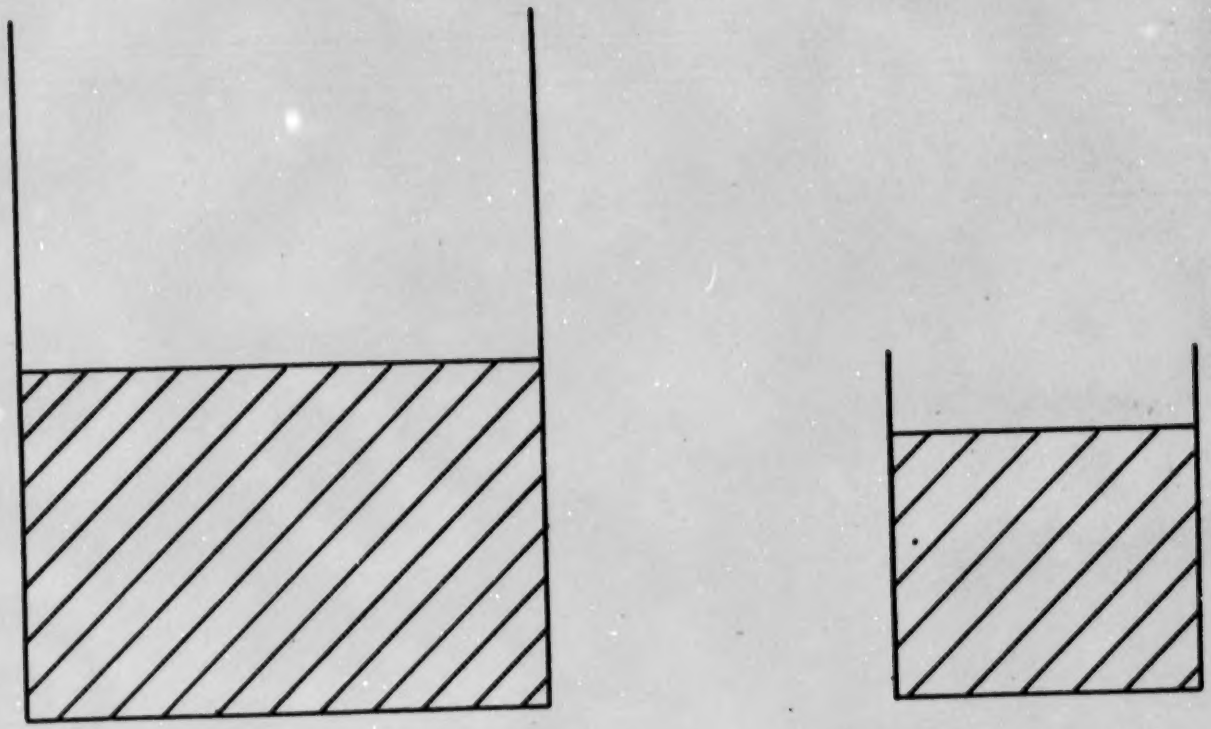

Figure 4

Experiment 4. The glasses used for the 3 judgements in the training session

Figure 4

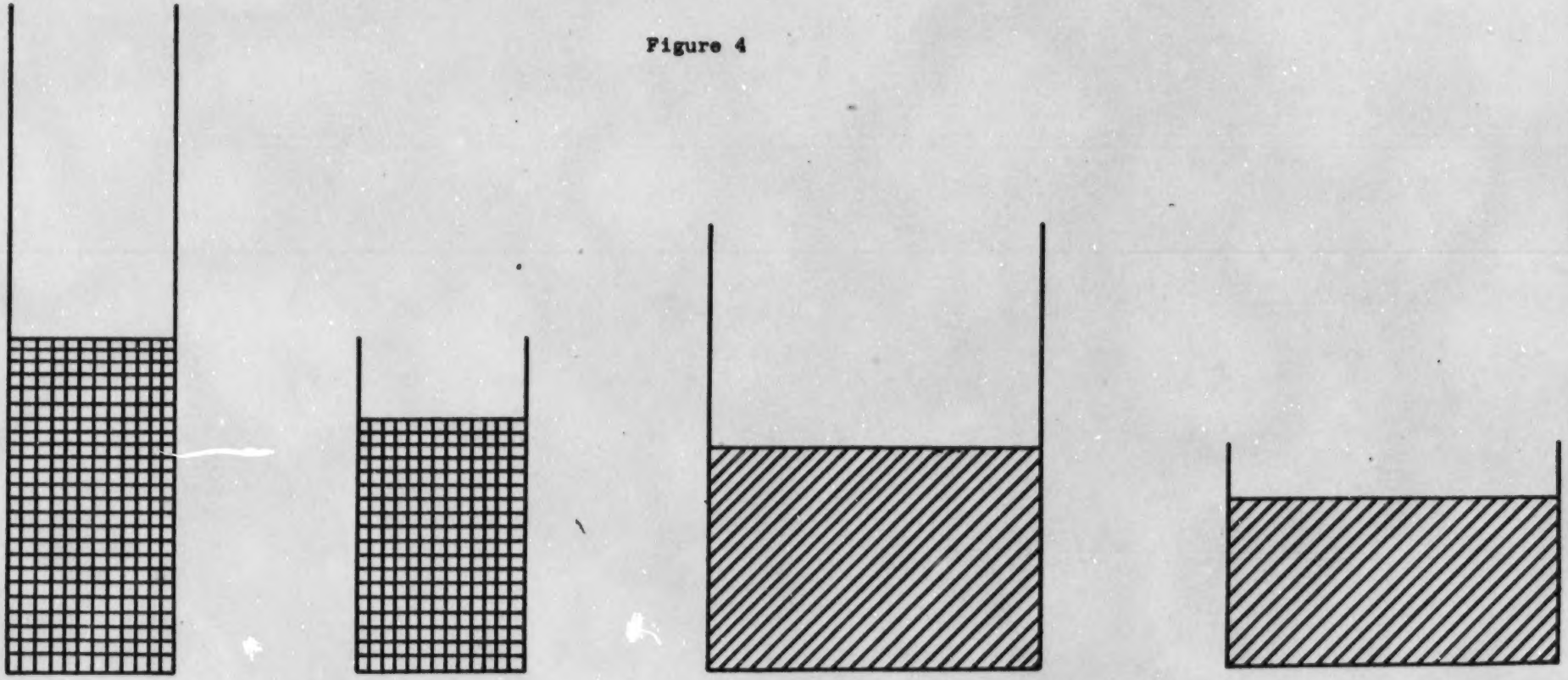

Figure 5

Experiment 4. The glasses used for the post-test.

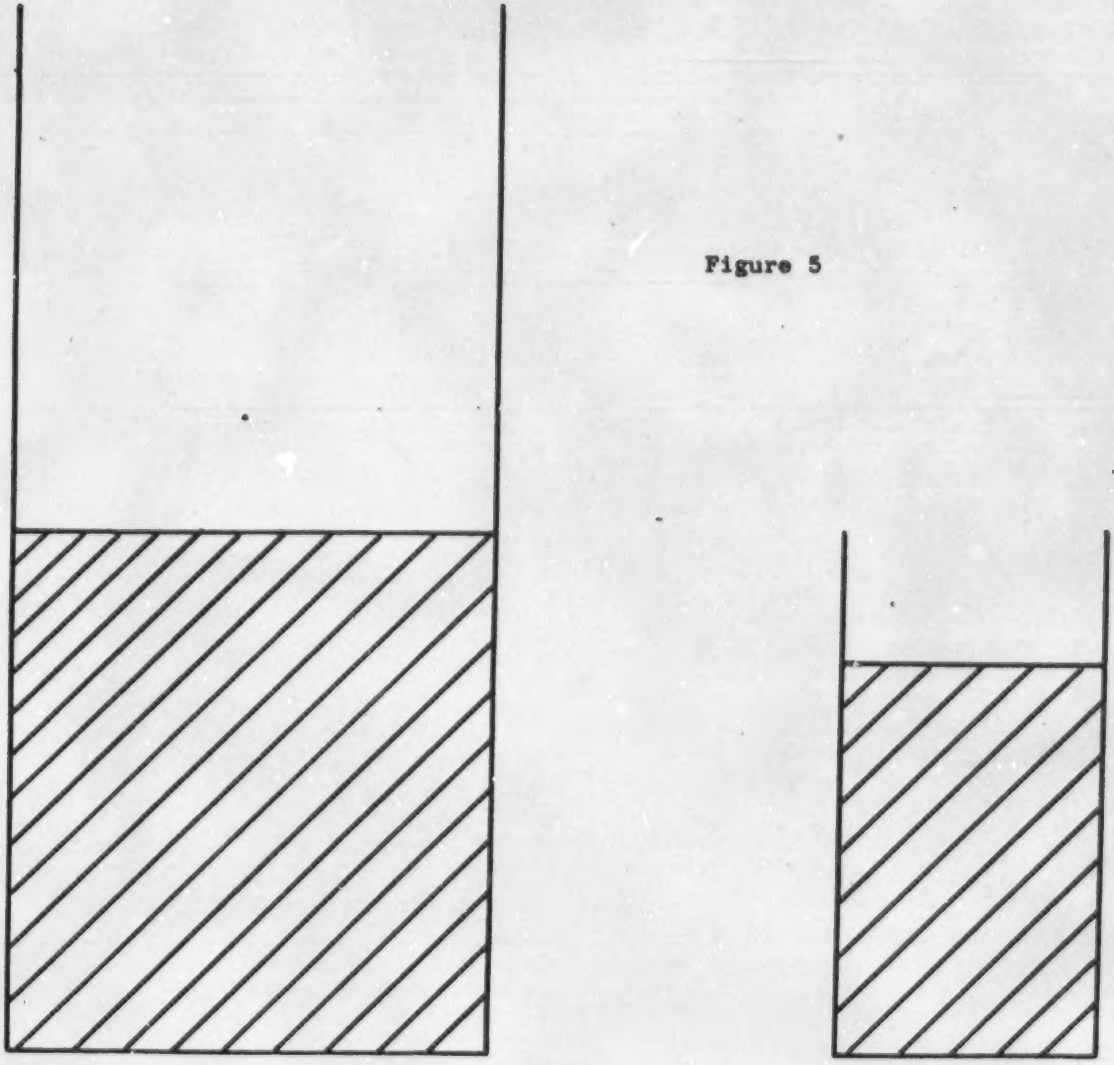

Figure 5

TABLE 1. NUMBER OF SUBJECTS WHO REFERRED

EXPLICITLY TO THE FUNCTIONAL CONTEXT

AGE IN YEARS	TOTAL NO. OF SUBJECTS	CONTEXTUAL REFERENCES				
		PLATE	CHOCOLATE OR CAKE	PIECE OR SLICE	AMOUNT MISSING OR REMAINING	PROPORTION FULL
5	11	-	3	2	6	-
6	17	1	4	1	11	-
7	12	1	2	1	9	2
8	20	-	3	5	12	-
9	20	-	4	1	14	1
10	16	-	1	5	10	-
11	22	2	1	2	14	4
ADULTS	5	-	-	-	5	-
TOTALS	123	4	18	17	81	7
PERCENTAGES	38.4	(N=21)	5.6	5.3	(N=81)	25.3

TABLE 2. MEAN SCORES (N = 8) FOR EACH TYPE OF RESPONSE

Age	Ratio	Relative	Error
4 years	2.7	3.1	2.5
7	4.2	3.2	0.5
10	4.9	3.0	0.3
adults	6.2	1.6	0.2

TABLE 3 JUSTIFICATIONS GIVEN BY THE ADULT SUBJECTS (N = 32)

Response	Percentage
Don't know	8
Centre angles of white segments	11.5
Lengths of arcs of white segments	19
Widths or 'sizes' of white segments	50
Proportions of white and brown	11.5

TABLE 4 NUMBER OF SUBJECTS WHO CHOSE EACH OF THE STIMULI

Age Group	Smallest	Middle Size	Biggest	Totals
5 years	4	1	14	19
6	5	1	13	19
7	5	1	13	19
Totals	14	3	40	57

TABLE 5 NUMBER OF BOXES LIFTED

PRIOR TO FINAL CHOICE OF STIMULUS

	NUMBER OF SUBJECTS		
Number of boxes lifted	Correct Choice	Middle Size	Biggest
0	2	1	40
1	0	1	0
2	2	1	0
3 (or >3)	10	0	0

TABLE 6 PERCENTAGE OF SUBJECTS CORRECT FOR EACH JUDGEMENT

Age Group	Number of Subjects	Pretest: "fuller"	Choice: Nearly full	Choice: Half-full	Choice: Nearly full	Choice: Half Full	Post-test: "fuller"
4 years	64	22	58	41	63 (N=32)	63 (N=32)	55
7 years	64	22	66	81	87 (N=34)	74 (N=30)	72
10 years	64	20	70	94	100 (N=37)	89 (N=28)	58

TABLE 7 NUMBER OF SUBJECTS (N) AND PERCENTAGES CORRECT (P) IN EACH CONDITION

Conditions	Diagram					
	Before Story		After Story		Totals	
	P	N	P	N	P	N
Gave fuller glass	59	34	48	29	54	63
Took fuller glass	68	37	58	31	63	68
Totals	63	71	53	60	58	131